



APPLICATION  
FOR  
UNITED STATES LETTERS PATENT

TITLE: DYNAMIC HISTOGRAM EQUALIZATION FOR HIGH  
DYNAMIC RANGE IMAGES

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# DYNAMIC HISTOGRAM EQUALIZATION FOR HIGH DYNAMIC RANGE IMAGES

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims benefit of U.S. Provisional  
 5 Application No. 60/179,308, filed January 31, 2000.

## BACKGROUND

Images can be represented as electronic versions of the scene being viewed. The electronic image may represent a scene that has a very high dynamic range, e.g. 18 bits or more of dynamic range. However, conventional display devices typically only display 8-bit images. Therefore, it is often necessary to display a higher dynamic range scene on a lower dynamic range viewing device.

If the same quantization step is used in an attempt to make this display operation, then either the brightest part of the image or the darkest part of the image is often lost.

## SUMMARY

20 The present application teaches nonlinearly mapping an image with higher number of bits to an image with a smaller number of bits, while preserving at least part of the local contrast.

According to the present system, this is done by using a local transformation that can rapidly change characteristics of the image.

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# BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will now be described in detail with reference to the accompanying drawings, wherein:

Figure 1 shows a block diagram of an imaging system using the present system;

~~Figure 2 shows an example histograms,~~

Figure 3 shows a mapping curve for the histogram of figure 2;

Figure 4 shows a histogram of the final compressed image; and

Figure 5 shows a flowchart of operation of the processor.

## DETAILED DESCRIPTION

An embodiment is shown in Figure 1. In the Figure 1 embodiment, an imaging system, generally shown as 100, obtains an image of the scene 110. The image may be obtained by an image acquisition device 120, which may include an active pixel sensor 122 receiving light indicative of the image of the scene 110, and converting that light into a signal 124 indicative of pixel-level received signals. A processor 130 may process this

image in a specified way as described herein, to reduce the number of bits of signal dynamic range. The output of the processor may be displayed on the display 140. For this purpose, the processor 130 may also include a display driver.

5 In this embodiment, the image 124, which is produced by the image sensor 122, may have a higher dynamic range that is capable of being displayed on display 140. Accordingly, the operation of the present system modifies the histogram of the image. The processor does this by carrying out the flowchart of Figure 5.

At 500, an initial operation calculates an image histogram. The histogram is shown as 200 in Figure 2.

The histogram is analyzed at 510. On typical analysis, 90 percent of the pixel values will often gather around several gray levels. Other gray levels typically have very few pixels falling on them.

~~Figure 2 shows the situation where most of the pixels falling within two areas. This can be applied to an image by selecting the two largest peaks, or by using multiple peaks.~~

20 In Figure 2, the peaks are shown as 210 having a width  $W1$  and 220 having a width  $w2$ . The centerline of the first area is labeled as  $loc1$ , and the centerline of the second area is labeled as  $loc2$ .

The present system compresses the image in a way such that the areas which have more common values are allocated to receive more gray levels. Fewer numbers of gray levels are allocated to other values which have fewer pixels falling on them. An attempt is also made to preserve the relative brightness.

At 520, the histogram is mapped, using the centerline locations loc1, loc2, and the widths of the peaks w1 and w2. A monotonous increasing mapping curve path (g) is formed. This curve path is monotonic, in the sense that it is continually increasing. However, it is non linear, in the sense that its slope is changing

The slope of the histogram mapping curve is highest in the areas of the peaks of the actual image histogram. Figure 3 shows the mapping curve used for the example histograms in Figure 2. The slopes are increased in the areas of Loc1 and Loc2.

The mapping curve uses the sigmoid functions for each of the peaks:

$$f(g) = \frac{-1 + \exp \frac{g - loc1}{w1}}{1 + \exp \frac{g - loc1}{w1}} + \frac{-1 + \exp \frac{g - loc2}{w2}}{1 + \exp \frac{g - loc2}{w2}} \dots$$

where g is the gray level. If more than two peaks are present, then more terms can be added. In general, all points

are scaled based on their relationship with the position of the maximum ( $g - loc_x$ ), weighted by the width of the peak ( $w_x$ ).

*Sub 9a3*  
~~The mapping curve is then scaled at 520 to scale the mapping curve between zero and  $2^8 = 255$  according to:~~

*Sub 9a4*

$$m(g) = 255 \times \frac{f(g) - f(\min(g))}{f(\max(g)) - f(\min(g))}$$

Where  $g$  is the original gray value, and  $m(g)$  is the compressed gray value. This mapping technique maintains the image after mapping to keep both the local and global constraints of the original image.

The scaled image forms a new histogram at 540. The new histogram is shown in Figure 4. In this histogram, the basic shape of the histogram space is the same. That is, the heights of the peaks in the new histogram may be in new compressed locations, but the heights of the peaks keep the same relationship as in the original histogram. However, the number of levels are compressed to the required number of bits, to allow the image to be displayed on a lower dynamic range display.

The above has described how to map the image to an 8-bit image. However, more generally, the image can be mapped to  $2^n$  gray levels, by using the more general scaling equation shown below.

$$m(g) = (2^n - 1) \times \frac{f(g) - f(\min(g))}{f(\max(g)) - f(\min(g))}$$

Although only a few embodiments have been disclosed in detail above, other modifications are possible. For example, this system can of course be used with other kinds of images besides the image from an active pixel sensor. In addition, different numbers of bits can be used. While this shows using only the most prominent two histogram peaks, more than two histogram peaks may be used. While this describes being used for gray levels, it more generally can be used with any kind of dynamic range levels, such as number of colors and the like.

All such modifications are intended to be encompassed within the following claims, in which: